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VOLUME 3

ANALYSIS OF PILOT PLANT ALTERNATIVES FOR THE INCINERATION OF BASIN F WASTES AT ROCKY MOUNTAIN ARSENAL

SEPTEMBER 1988

TASK NO. 17

CONTRACT NO DAAK11-84-D-0017

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EBASCO SERVICES INCORPORATED

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1.0 INTRODUCTION

The Program Manager's Office (PMO) for Rocky Mountain Arsenal (RMA) Contamination Cleanup is gathering information on the technical and economic aspects of incineration/thermal treatment of Basin F wastes. This information gathering process is one aspect of developing a remedial action alternative for Basin F. The PMO has taken this action in accordance with the National Contingency Plan, 50 Federal Register 47912 (1985). Accordingly, the PMO has contracted Ebasco Services Incorporated (Ebasco) to conduct this work effort under Task Order 17.

1.1 SCOPE OF WORK

Task Order 17 consists of five distinct work objectives:

- o Selection of a preferred incineration technology through a literature review;
- o Determination of thermal decomposition characteristics for Basin F wastes through laboratory investigations;
- o Formulation and evaluation of pilot plant alternatives;
- o Conceptual design of a full-scale system based on the selected incineration technology with sufficient details to allow development of capital and operation and maintenance cost estimates; and
- o Expansion of the laboratory investigations to include Section 36 wastes.

The purpose of this report is to develop and evaluate pilot plant alternatives. The goal of the pilot plant program is to reduce uncertainties in the design and operation of a full-scale incineration system.

1.2 BASIS FOR THE PILOT PLANT

Criteria for evaluating pilot plant alternatives were developed based on information contained in the following reports:

- "Selection of Incineration Technology for Basin F Wastes at Rocky Mountain Arsenal" (Technology Selection Report), September 1988 (Ebasco 1988a). This report recommends rotary kiln/afterburner technology for incinerating Basin F wastes.

- "Bench-Scale Laboratory Incineration of Basin F Wastes at Rocky Mountain Arsenal" (Basin F Laboratory Report), September 1988 (Ebasco 1988b). This report presents the laboratory data generated from test burns of Basin F overburden material. The report specifies conservative combustion conditions for achieving a 99.99 percent destruction and removal efficiency (DRE) of organics present in the Basin F materials.

- "Full-Scale Incineration System Conceptual Design for Basin F Waste at Rocky Mountain Arsenal" (Full-Scale Conceptual Design), September 1988 (Ebasco 1988c). This report presents the conceptual design of a full-scale incineration system based on the rotary kiln afterburner technology, which is capable of thermally treating Basin F wastes in a 2.5-year time frame. The report also presents an order of magnitude (+25 percent and -10 percent) capital and operation and maintenance cost estimate for a full-scale system.

1.3 REGULATORY CONSIDERATIONS FOR THE PILOT PLANT PROGRAM

On October 17, 1986, the President signed into law the "Superfund Amendments and Reauthorization Act of 1986." These amendments to the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) include a new Section 121, which specifies a number of criteria to be considered in determining the appropriate cleanup standards applicable to remedial actions taken pursuant to the Act. Subsection 121(b) makes clear that Section 121 applies to Rocky Mountain Arsenal cleanup.

New Section 121(e) provides that "No federal, state, or local permit shall be required for the portion of the removal or remedial action conducted entirely on-site, when such remedial action is selected and carried out in compliance with this section." Accordingly, no federal or state permit is needed for activities related to the on-site incineration pilot plant.

Section 121 also provides that, resulting from a response action, a hazardous substance, pollutant, or contaminant must at least attain the level of control that is provided by an "applicable or relevant and appropriate standard, requirement, criteria, or limitation ('ARAR')." ARAR may include both state and federal requirements. Pursuant to Section 121(d)(2)(a), ARARs include the following:

> "(i) any standard, requirement, criteria, or limitation under any Federal law, including, but not limited to the Toxic Substances Control Act, the Safe Drinking Water Act, the Clean Air Act, the Clean Water Act, the Marine Protection Research and Sanctuaries Act, or the Solid Waste Disposal Act, or
>
> "(ii) any promulgated standard, requirement, criteria, or limitation under a State environmental or facility siting law that is more stringent than any Federal standard, requirement, criteria, or limitation contained in a program approved, authorized, or delegated by the Administrator under a statute cited in subparagraph (A), and that has been identified to the President by the State in a timely manner."

To assure compliance with this CERCLA requirement, a determination will be made as to which state or federal ARAR is applicable to the specific pilot plant alternative selected for implementation.

Section 121 also outlines certain exceptions to the general rule that remedial actions must attain state and federal ARARs. For example, an otherwise applicable ARAR need not be attained where compliance "is technically impracticable from an engineering perspective" (Section 121(d)(4)(c)). Hence, Section 121 requires a determination of which of the Section 121 exceptions, if any, apply to the selected alternative.

The above is a general overview of the applicable regulations. A review of applicable federal, state, and local permits and regulations is required at the time the pilot plant alternative is implemented.

1.4 REPORT ORGANIZATION

In Section 2.0, important pilot plant selection criteria are identified. In Section 3.0, pilot plant alternatives are described and compared to the selection criteria. In Section 4.0, one alternative is selected.

Appendix A contains responses to Shell Oil comments pertaining to the previous draft of this report, while Appendix B contains the response to the U.S. Environmental Protection Agency Region VIII comment. References cited in this report are listed in Appendix C.

2.0 SELECTION CRITERIA FOR THE PILOT PLANT

This section describes the objectives of the pilot plant and the importance of selected design and operating variables.

2.1 OBJECTIVES OF THE PILOT PLANT

The fundamental objectives of a pilot plant for Basin F wastes at Rocky Mountain Arsenal are as follows:

- Reproducibility of design parameters;
- Intermediate-scale testing;
- Determination of failure points; and
- Determination of final design parameters.

2.1.1 Reproducibility of Design Parameters

One purpose of the pilot plant is to determine, through operating experience, if the given design concept works. In the case of rotary kilns, the pilot plant should reproduce the fundamental kiln and afterburner variables as obtained from the reports discussed previously in Section 1.0 of this report. Important variables developed from these reports for the full-scale system are presented in Table 2.1-1. Also presented is the range in variables that the pilot plant must duplicate to allow evaluation at different conditions and to determine failure points.

TABLE 2.1-1

CONSERVATIVELY DETERMINED FULL-SCALE SYSTEM VARIABLES
VERSUS THE RANGE OF VALUES REQUIRED OF THE PILOT PLANT

Parameter	Full-Scale System Values	Range of Variables Required of Pilot Plant
Kiln Gas Temperature, °C	900	800-1,100
Solids Approach Temperature, °C	200-300	100-300
Kiln Solids Temperature, °C	600-700	600-800
Kiln Solids Residence Time, min	30	15-60 1/
Kiln Loading, percent	6-8	6-10
Afterburner Temperature, °C	1,200	1,000-1,300
Afterburner Gas Residence Time, sec	2	2-3
Afterburner Orientation	Vertical/ Down Flow	Vertical/ Down Flow
Kiln Excess Air, percent	50	35-70 2/
Afterburner Excess Air, percent	25	20-50 2/
Fuel Type	Natural Gas and No. 2 Fuel Oil	Natural Gas and No. 2 Fuel Oil
HCl Removal, percent	99+	99+
SO_2 Removal, percent	95+	95+
Particulate Removal, grains/sdcf	0.01 3/	0.01 3/

1/ Kiln drum drive includes a variable speed device to adjust the solids residence time.

2/ Variation in levels of excess air are used to vary the gas residence time in the kiln and afterburner.

3/ Particulate controlled to 0.01 grains/sdcf corrected to 12 percent carbon dioxide.

2.1.2 Intermediate-Scale Testing

The pilot plant represents the first step in scale-up to a commercial operation. It is the stage when automated controls are added, control systems evaluated, and materials of construction (e.g., refractory linings) selected. The pilot plant provides a basis for scale-up analysis in terms of final technical and economic feasibility analysis (Sweringen et al. 1985).

It is ideal to have a pilot plant sized to operate at a scale that is within one order of magnitude of scale-up to a single process train in the full-scale system at Basin F (see ESCOE 1979 for a discussion of the scale-up process). Given the proven nature of this technology, exceeding one order of magnitude is possible. A single rotary kiln and afterburner unit train (two trains total) has a design capacity of 20 tons/hr based on the conceptual design. The pilot plant should have a capacity of 2,000-3,000 lb/hr or demonstrated scalability to a full-scale system. This provides for the maximum reduction of uncertainty when designing and installing the full-scale system.

2.1.3 Determination of Failure Points

A properly designed and operated pilot plant provides proof of the design concept with particular emphasis on an operating regime for the incineration of Basin F wastes. Further, multiple test runs are used to determine under what conditions the full-scale system might fail to achieve 99.99 percent DRE. This testing includes such operating parameters as the following:

- o Residence time and temperature in both the kiln and afterburner;
- o Quench tank parameters for temperature reduction; and
- o Kiln loading levels.

During pilot plant operation, tests are performed with the kiln operating in transient or upset conditions.[1/] Such tests aid in the development of control systems and strategies designed to minimize the risks associated with upset conditions.

In addition to not achieving 99.99 percent DRE, failure can be indicated by maintenance required because of construction materials (e.g., corrosion or erosion of refractory). These failures can only be estimated by pilot testing.

2.1.4 Determination of Final Design Values

The data obtained from the pilot testing are used to select the final system design parameters. Such a design reflects both the basic design concept along with modifications resulting from the pilot plant program. Such modifications of parameters may occur in (but not be limited to), the following areas:

- Combustion regime;
- Fuel selection;
- Control systems;
- Materials of construction;
- Operational procedures;
- Emission controls; and
- Safety systems.

1/ During transient and upset conditions, the afterburner may release principal organic hazardous constituents (POHCs), which are not destroyed to 99.99 percent. If this is the case, carbon absorption or a fume incinerator may be required before the gases are exhausted to the atmosphere.

2.1.5 The Range of Pilot Plant Options Being Considered

Four pilot plant alternatives are being considered:

- o No Pilot Plant Alternative;
- o Use of Building 1611;
- o Installation of a Mobile or Permanent Pilot Incinerator On-Site; and
- o Shipment of Basin F Wastes to an Off-Site Incinerator.

2.2 IMPORTANCE OF VARIABLES

In order to stress the importance of the pilot plant, a brief discussion is presented on selected parameters.

2.2.1 Kiln Loading

In the conceptual design report, kiln loading was limited to 6-10 percent of the cross-sectional area to minimize the premature loss of solids from the rotary kiln before the desired residence time expired. If the pilot plant program shows favorable results at a kiln loading of, for example, 10 percent compared to 6 and 8 percent, the individual kiln capacity could be increased by a factor of 1.25 or 1.65. Obviously, kiln loading plays an important role in the sizing of a rotary kiln. As a result, kiln loading must be accurately determined during the pilot plant program.

2.2.2 Solids Residence Time

Another key design parameter is the solids residence time. For the full-scale plant, a solids residence time of 30 minutes is assumed. This could vary for the following reasons:

- o The Hittman-Ebasco tests involved nonflame mode destruction;
- o The Hittman-Ebasco experiments were not designed to quantify the primary reactor solids residence time;

- The results of tests on clays under the liner indicated that contamination exists below the liner, and possibly more pure clay or unknown soil types may need to be incinerated; and
- Changes in kiln loading.

All of the above parameters affect the heatup rate of the solids and subsequently the total residence time of the solids in the rotary kiln. Residence time is measured from the feed of the solids into the kiln to the time it takes the material to exit the kiln at the discharge end. A solids residence time of 30 minutes is used for the conceptual design, at a peak gas temperature of 900°C. However, the average solids temperature of a particle traversing the kiln is only 600 to 800°C.

The solids must be at sufficient temperature long enough to volatilize the POHCs and other toxic compounds. As previously discussed, the type and operating conditions of the Hittman-Ebasco test apparatus were not designed to determine the heatup rate or solids residence time in the primary reactor. However, these tests would not be representative, as bulk heat transfer properties of the kiln are not replicated as indicated below:

- The thermal energy in the refractory is not represented accurately;
- The tests are nonflame mode;
- Bulk considerations of the soil matrix are not representative; and
- Solids mixing caused by kiln rotation is not accurately duplicated.

The full-scale design used a solids residence time of 30 minutes. If the solids residence time is increased to 60 minutes, the kiln capacity is reduced by a factor of 2. On the other hand, if the solids residence time is reduced to 15 minutes, the kiln capacity is increased by a factor of 1.5. Obviously, this type of variation cannot be tolerated in a full-scale system since it could significantly affect the schedule of a project if kiln capacity is reduced. As a result, kiln capacity must be accurately determined. This parameter can only be determined in a pilot plant unit.

2.2.3 Flame Mode Destruction

The Hittman-Ebasco tests were not representative of flame mode destruction. The primary reactor (rotating reactor) and the afterburner are heated by electric resistance heating. Flame mode heating adds another dimension to the operation of the kiln and afterburner. Heating is provided by radiation from the flame as well as the refractory. Gas volumes are significantly increased, which affects the gas residence time. Fuels under consideration for the full-scale system include natural gas and No. 2 oil. Each of these fuels requires a different burner design and support equipment. Further, each fuel has a different flame shape, temperature profile, heat transfer properties, and products of incomplete combustion (PICs). As a result, tests on flame mode destruction represent an important aspect of the pilot plant test program. Also, the fuel is the most expensive operational cost. Fuel savings are therefore important.

2.2.4 Soil Type

Many rotary kiln systems have been built to produce cement or calcine lime. Mineral processing kilns have been built to process silica-bearing soils. The material at RMA is characterized by particle sizes ranging from sand to clay, having virtually no heating value. As previously indicated, the material under the liner is mostly clay. At this time, it is not understood how the clay material behaves in a rotary kiln. For example, it is not known whether the rotational motion of the kiln causes sufficient mixing of the clay layer or whether a ram feeder feeds the material or compresses it into chunks. As a result, the pilot plant should have provisions for a ram feeder.

2.2.5 Cocurrent Versus Countercurrent Burner Location

Specifically, there are three general reasons why cocurrent operation is favored over countercurrent operation. The first reason is that in countercurrent operations, the temperature of the exhaust gases is lower, and one of the big energy consumption variables is the temperature differential between the off gas from the kiln and the temperature in the

secondary combustion chamber. More energy is expended heating up gas than is expended heating up solids. A second, and more important, issue is that there is no guarantee of solids residence time in the kiln for entrained solids in countercurrent flow. Solids enter at the cool end of the kiln rather than at the hot end. If solids are entrained, they never encounter the flame or hot zone of the primary reactor. Consequently, the only high temperature such entrained solids particles will encounter is that in the secondary combustion chamber.

The third area of concern relates to material feeding. In countercurrent operations, the solids are fed at the end where the product gases are coming off, which complicates the mechanical design. Further, solids are discharged at the hot end of the kiln. While this is readily accomplished, particularly in the case of cement kilns, it increases the system complexity and capital cost. Further, countercurrent operation is typical of cement kilns in the slagging mode. If this mode of operation is used, very high temperatures in the kiln would be achieved. Slagging operation is not considered desirable at this time. As a result, cocurrent operation is selected.

2.2.6 Slagging Operation

A rotary kiln operates either in the nonslagging mode or the slagging mode. In the slagging mode, the thermally treated residue is discharged as a liquid. It is cooled and then disposed of as a solid. In the nonslagging mode, the thermally treated soil is discharged as hot soil. There may be salt melting and/or volatilization, but the material exits the kiln as a solid. A slagging kiln is designed to hold a pool of molten material. As a result, a nonslagging kiln cannot be operated in the slagging mode. Nonslagging operation is selected since in the Basin F Laboratory Report the thermally treated residue passes the total concentration leachate procedure (TCLP) and also because the soil has a high fluid temperature (as indicated by the ash fusion determination).

The above discussion outlines the importance of a good pilot plant program. In the following section, the various alternatives are evaluated.

3.0 PILOT PLANT ALTERNATIVES

Pilot plant alternatives that are considered in this section include the following:

- The No Pilot Plant Alternative;
- The Building 1611 Pilot Plant Alternative;
- The On-Site Permanent or Mobile Pilot Plant Alternative; and
- The Off-Site Pilot Plant Alternative.

The No Pilot Plant Alternative involves more extensive laboratory testing of Basin F wastes to establish system design parameters. The Building 1611 Pilot Plant Alternative utilizes an existing rotary kiln, afterburner, and pollution control equipment located in Building 1611 at Rocky Mountain Arsenal. The Building 1611 system is currently not operational. The On-Site Permanent or Mobile Pilot Plant Alternative involves either the construction or leasing of a pilot plant incinerator for use at Rocky Mountain Arsenal. The permanent on-site and mobile systems are classed together, since they are different forms of the same alternative (i.e., an on-site incinerator), and because the site requirements are similar. The Off-Site Pilot Plant Alternative involves shipping Basin F materials to an off-site facility that is capable of meeting the conceptual design requirements. Off-site incinerators include pilot-scale equipment at vendor facilities and existing commercial full-scale hazardous waste incinerator facilities.

3.1 ANALYSIS OF THE NO PILOT PLANT ALTERNATIVE

The No Pilot Plant Alternative relies on the test results developed by UBTL, CAL LABS, and Hittman-Ebasco, plus additional laboratory testing for the design of the full-scale incinerator facility for Basin F wastes. Assistance may be available from vendors of rotary kiln systems, the literature, and currently operating units.

Hittman-Ebasco Laboratory conducted laboratory research into using long residence time reactors followed by an afterburner to destroy the Basin F material. The use of rotary kiln technology and its associated operating conditions are well established for processing limestone, cement, and hazardous wastes. Thus, a considerable amount of information and expertise exists that could assist in the design of a rotary kiln incinerator facility for Basin F material. The question is, then, what risks and costs are associated with not utilizing a pilot plant for the incineration of Basin F wastes?

3.1.1 Description of the No Pilot Plant Alternative

The No Pilot Plant Alternative is based upon the assumption that there is sufficient data associated with the laboratory analysis of Basin F wastes, and that this laboratory analysis, coupled with previous experience in rotary kiln design and operation, and additional laboratory testing (as required), is a suitable substitute for pilot plant testing. Research into the solids residence time in the primary reactor would need to be conducted. The Hittman-Ebasco tests have very conservatively established the afterburner and kiln operating parameters. Failure mode has also been determined for the afterburner on a nonflame mode system for PICs. Failure mode has not been determined with regard to the solids residence time in the rotary kiln. Again, it must be stressed that the laboratory work was done on a nonflame mode unit. Additional laboratory tests that could be substituted for pilot plant experience would include the following:

- o The physical, chemical, and thermodynamic (PCT) characterization of Basin F wastes;

- o Additional regime testing using a flame-mode incinerator to determine the optimum residence time, temperature, and level of excess air to be used in incinerating Basin F wastes, including solids residence times in the rotary kiln; and

- The PCT characterization of the resulting residue (ash) from the kiln and afterburner.

The PCT characterization of the waste materials to be processed includes EP toxicity, total concentration leachate procedure, elemental analysis, moisture content, heat capacity, ash fusion temperature, corrosiveness, reactivity, specific heat, thermal conductivity, and related parameters such as elemental and trace metal analyses. This laboratory testing is described in detail in the final report titled "Laboratory Test Plan for Incineration of Basin F Wastes at Rocky Mountain Arsenal," April 1987 (Ebasco 1987). Additional PCT characterization will provide the basic design data concerning the Basin F materials. Most of the tests listed above would be required no matter which pilot plant alternative is selected. However, for the No Pilot Plant Alternative, more extensive testing of design parameters would be required.

The Hittman-Ebasco Laboratory testing is designed to determine the following:

- Appropriate POHCs for determination of the destruction efficiency of an incinerator system; and

- Optimal combustion regime (time, temperature, and level of excess air) and residence times for the incineration of Basin F wastes.

As previously noted, a laboratory test unit has been constructed according to the design described by Ebasco (1987). That test unit, shown schematically in Figure 3.1-1, permits incineration of 300 gram samples in a rotary reactor. Electricity is used to heat the kiln and afterburner. The Hittman-Ebasco test unit does not provide for flame mode destruction of hazardous wastes.

The data developed by the PCT testing and by the Hittman-Ebasco test unit can be augmented by prior vendor experience as well as additional test burns at facilities with flame mode incineration. Numerous vendors who supply rotary kilns to the hazardous waste industry, the minerals industry, and the

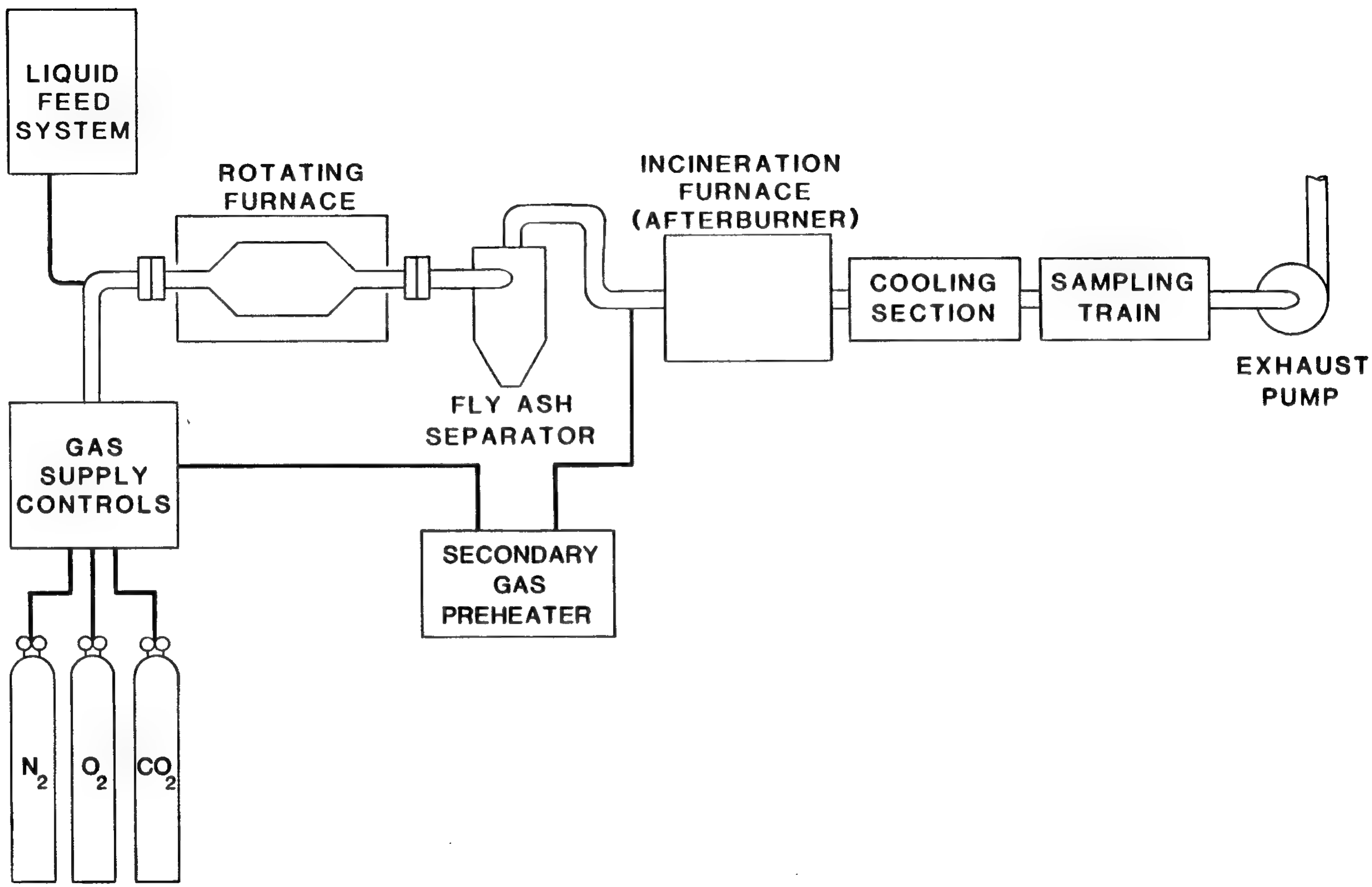

FIGURE 3.1-1

LABORATORY SCALE INCINERATION UNIT

pulp and paper industry have sufficient experience to aid in the final design of a system, assuming conventional or previously utilized feedstocks.

The No Pilot Plant Alternative assumes that sufficient information exists on rotary kilns, and that sufficient properties data exist or will be developed on the materials at Basin F, to allow implementation of the final design when the decision to incinerate is reached. Further, the final design of the incineration facility would be more conservative without the pilot plant program and, as such, would have a higher capital, risk, and operating and maintenance costs.

3.1.2 Assessment of the No Pilot Plant Alternative

The No Pilot Plant Alternative offers both cost and time savings. In terms of dollar expenditures, no costs associated with pilot plant testing would be incurred. Dollar expenditures saved include renting or building either an on-site incinerator or having tests conducted at an off-site facility.

The time savings for the No Pilot Plant Alternative is likely to be 6 to 9 months, depending on the option chosen. This 6 to 9 months does not include the time required to specify, engineer (if required), lease, build, or start-up an on-site pilot plant incineration unit or comply with ARARs.

The weaknesses associated with this approach are significant. Assuming that one process kiln and afterburner train in the full-scale incinerator will have a design capacity of 20 tons/hr of material, and recognizing that the Hittman-Ebasco test apparatus processes 300 grams of material per test, the scale-up ratio is approximately 50,000 or four orders of magnitude.

Further, the Hittman-Ebasco and other bench-scale test units are not designed to be, or function as, a true process simulator, since they are batch process laboratory systems and do not employ flame mode destruction.

Rather, they utilize indirect resistance heating of the solids and gases in place of radiant and convective heating from the combustion of oil or gas. Because of the electrical resistance heating and the length of time required

to reach temperature, the unit cannot be used to establish a minimum solids residence time in the primary reactor or duplicate actual kiln operating parameters. Also, the Hittman-Ebasco and other bench-scale units are not constructed with materials that are similar to those in a full-scale system, and the afterburner is a fused quartz tube rather than a refractory-lined combustion chamber.

The Hittman-Ebasco test unit can simulate the temperatures, residence times, and levels of excess air for the afterburner, but not the solids residence time (in a nonflame mode) of the kiln as planned for the full-scale unit. It cannot offer any guidance concerning the capital and operation and maintenance cost of the full-scale system. Of particular importance is the integrity of the refractory when the materials from Basin F are being subjected to high temperatures in an oxidizing environment. However, vendor input and testing could be used to select an appropriate refractory for the facility's expected life, but the information would be conservative and would represent more expensive materials of construction.

If the No Pilot Plant Alternative is chosen, the full-scale system design must utilize the most conservative factors in the selection of basic design parameters as indicated below:

- o Kiln loading; and
- o Kiln solids residence time.

These factors are critical to the design of the incinerator. To remain conservative, a high kiln loading would be used to limit premature solids losses. The solids residence time is critical, as it determines the degree of utilization. Variation in both of these parameters would significantly affect the capital and operating and maintenance cost of the incinerator program.

The use of the No Pilot Plant Alternative is associated with a higher capital, risk, and operating and maintenance cost for the full-scale system. The alternative also has a higher possibility of failure because it

does not provide for a complete simulation of the full-scale process, and there is not adequate assurance that destruction of organics to 99.99 percent is achievable.

3.1.3 Conclusion

In summary, the No Pilot Plant Alternative offers only near-term monetary advantages. It avoids expenditures associated with the design and construction of a pilot plant, and saves time from the feasibility stage to the actual treatment of the Basin F wastes. However, the absence of a pilot plant increases the uncertainties associated with the final design and, as a consequence, increases the total cost and risk associated with the full-scale system. As indicated, conservative design factors would be required to compensate for increased uncertainty. Additional testing would also be required as previously discussed. As a result, the No Pilot Plant Alternative does not represent a sound engineering approach.

3.2 ANALYSIS OF BUILDING 1611 AS A PILOT PLANT

Another available option is the rehabilitation of the rotary kiln incinerator currently located in Building 1611. This option has the potential of reducing the cost of the pilot plant since an on-site or mobile facility would not be required.

However, the rotary kiln incinerator in Building 1611 is currently not in operation nor is it in an operational condition. The assessment of the Building 1611 option addresses the following issues: 1) the ability of the facility to be modified to simulate the full-scale system design; and 2) the current condition of the facility and the cost of rehabilitation.

The rotary kiln incinerator and operating data were examined by Ebasco to determine the condition of the unit and to determine whether the unit could simulate the operation of a full-scale system as proposed for the incineration of Basin F material. The Building 1611 incinerator was also examined by Stearns-Catalytic Corporation (Stearns 1986), the original engineer and constructor of the facility.

3.2.1 Description of Building 1611

The Building 1611 incinerator consists of a materials feeding section, a rotary kiln, an afterburner, a quench tank, an air quality control system (AQCS), residue conveyors and hoppers, and ancillary equipment. The kiln itself is enclosed and is operated under negative pressure. The afterburner, quench tank, and AQCS are not enclosed. A schematic representation of the Building 1611 kiln is shown in Figure 3.2-1.

The Building 1611 incinerator was originally developed for destruction of "Honest John" warheads, and, as such, its primary purpose was for incineration of munitions.

Building 1611 Kiln

The rotary kiln is constructed of a cast alloy. The rotary kiln is approximately 20 ft long and 3 ft in diameter, with an L/D ratio of about 6.7. The L/D ratio is significantly above the range of 3.2 to 3.3 for material comparable to that of Basin F and, as such, premature solids loss would be large. The kiln is not refractory lined and has an integral cast helix on its interior that causes the shells and other feed materials to proceed through the kiln at a rate proportional to the rotational speed of the kiln. This helix is not typical of hazardous waste kilns and precludes the addition of a refractory lining, which is required for optimal radiant heat transfer to the solid feed material.

The rotary kiln is fired with No. 2 distillate oil. The burner is located at the discharge end of the kiln rather than at the more conventional head end of the kiln. As a result, the kiln operates in a countercurrent mode with exhaust gases exiting across the feed input. Typical temperatures in the kiln are indicated below:

- o Exhaust gas temperature - 170-260°C
- o Maximum burner end temperature - 590°C

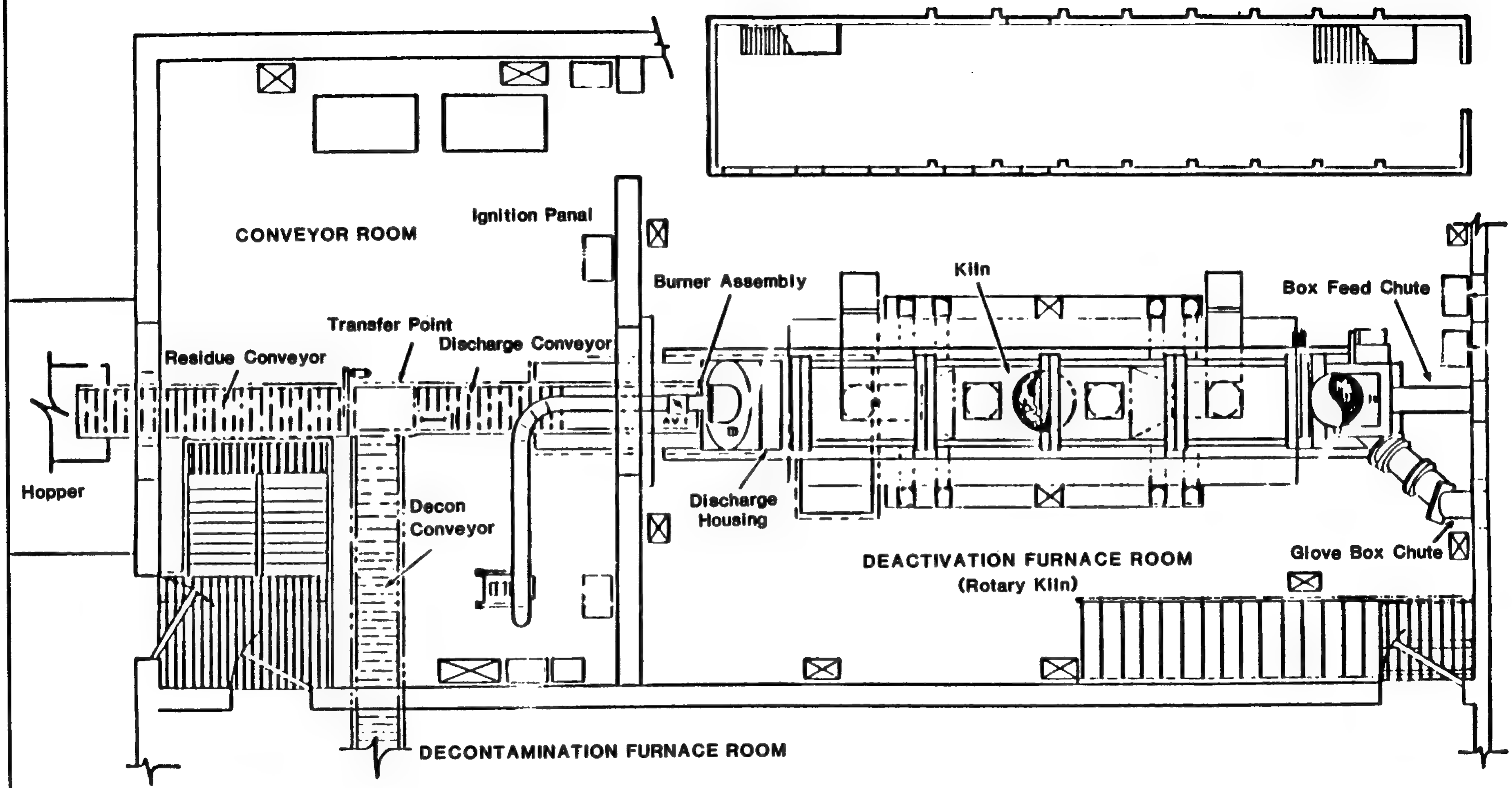

FIGURE 3.2-1

SIMPLIFIED SCHEMATIC OF BUILDING 1611 SYSTEM

These temperatures are insufficient for the incineration of Basin F material based on the Basin F Laboratory Report (Ebasco 1988b). At the operating temperatures of the Building 1611 kiln, a significant quantity of PICs would be formed when compared to the desired kiln operating conditions previously identified at 900°C for the gas and 700-800°C for the solids. The kiln cannot be overfired to get higher temperatures because it is not refractory lined and the gas residence time would decrease.

The residence time for solids in the kiln is about 36 minutes. Gas residence times vary over an indeterminate range. Residence times change as a function of when (and consequently where along the kiln axis) organics volatilize, due to the countercurrent nature of the unit.

Afterburner and Quench System

The afterburner associated with Building 1611 is a horizontally oriented, refractory-lined combustor located on the roof of the building. As with the kiln, the afterburner is not in operation at this time. It, too, is fired with No. 2 distillate oil. Its maximum design operating temperature is 900°C with a gas residence time of approximately 2 seconds. The operating temperature of 900°C is significantly below the desired operating temperature of approximately 1,200°C as established by the Hittman-Ebasco tests for PICs. Its exhaust is mixed with air from the furnace room in order to accomplish some cooling prior to entering the quench tank. The quench chamber at the Building 1611 incinerator uses evaporative cooling to reduce the products of combustion to a temperature of about 110°C. The quench liquid is held basic, at a pH of 9.0, with caustic (sodium hydroxide) addition. This quench chamber removes hydrogen chloride produced by the incineration of chlorinated compounds.

Air Quality Control System

The air quality control system designed for the incinerator at Building 1611 consists of a five-stage electrostatic precipitator (ESP). The ESP is followed by a packed tower scrubber used to remove gas vapors and acid mists.

3.2.2 Condition of the Facility

Stearns Catalytic examined Building 1611 for rehabilitation (Stearns 1986). Major problem areas identified are summarized below:

- o Nearly all of the equipment must be activated;
- o The worst equipment seems to be the HVAC ductwork;
- o Much of the control system is suspect;
- o Several of the supporting systems are damaged and/or partially disassembled;
- o The interior of the kiln is littered with debris;
- o The interior condition of the afterburner is not known;
- o The quench chamber has incrustation accumulations;
- o The receiving, handling, and disassembly area are in disarray;
- o The residue handling facilities appear to be in good condition;
- o The utility supporting systems seem to be operable; and
- o Ebasco contamination evaluations indicated that the entire interior of the building requires protective clothing, which includes wearing a mask at all times.

It is the conclusion of Stearns Catalytic Corporation that the facility could be rehabilitated and restarted in an expeditious manner. However, it is Ebasco's contention that the facility cannot meet the design conditions required and potentially cannot be modified in a cost-effective manner for the pilot plant to be representative of a full-scale system.

3.2.3 Assessment of the Building 1611 Option

As indicated in Table 3.2-1, there are major differences between the Building 1611 kiln and the design conditions. The operating conditions of the Building 1611 kiln and afterburner are unacceptable for the pilot plant. The system could not be modified to reproduce the design conditions as described below.

Adding refractory would increase the L/D ratio and lower both the gas and solids residences times. The kiln cannot be overfired to increase the

TABLE 3.2-1

COMPARISON OF BUILDING 1611 SYSTEM
TO THE PROPOSED SYSTEM DESIGN CONDITIONS

Parameter	Building 1611 System	Full-Scale Design Conditions
Kiln		
L/D Ratio	6.7	3.3
Maximum Solids Temperature, °C	600	600-700
Gas Exit Temperature, °C	170-260	900
Residence Time, minutes	36	30
Refractory	none	required
Firing	countercurrent	cocurrent
Afterburner		
Maximum Temperature, °C	900	1,200
Orientation	horizontal	vertical
Gas Residence Time, seconds	2	2

operating temperatures because it is unlined (and probably cannot be lined since the helix is cast into the shell and because the gas residence time would decrease). As the gas residence time decreases, carry-over increases. Further, the kiln would need to be changed from countercurrent to cocurrent operation by relocating the burner. The existing afterburner would need to be replaced with a downflow, vertical afterburner. Downflow vertical orientation is required in order to minimize salt attack on the refractory.

Beyond these necessary modifications, the entire system requires a new materials handling system. The current system is not capable of handling dirt or sludge.

In short, it is not possible for the Building 1611 incinerator to simulate the system and regime associated with the full-scale conceptual design. Modifications to the kiln and afterburner are limited by the dimensions, temperatures, and configurations of the equipment.

3.2.4 Conclusion

Given the inadequacy of Building 1611 to simulate the full-scale conceptual design, it is no longer considered a viable alternative for a pilot plant program.

3.3 THE ON-SITE PERMANENT OR MOBILE PILOT PLANT ALTERNATIVE

Two options exist for a pilot plant located at RMA: a permanent pilot plant (on-site) or a mobile pilot plant. The permanent pilot plant would be installed at RMA to support incineration of Basin F wastes. The permanent pilot plant could also be made available for the evaluation of other RMA wastes for incineration, if the need arises. The mobile incineration system would be used specifically for temporary on-site field operations. Each alternative has certain advantages, particularly with respect to cost.

A permanent on-site pilot plant includes equipment plus foundations and ancillary services designed to remain on-site for an extended period of

time. While it is a research tool, it is expected to have a life in excess of one year. An on-site facility requires site preparation and regulatory compliance that may affect the project schedule and budget. These considerations are discussed in the following sections.

A mobile incineration pilot plant system consists of equipment mounted on trailer(s) that are brought to the site, operated, then moved to the next site. This on-site operation eliminates the need to transport hazardous wastes to an off-site facility, although some foundations may still be required.

3.3.1 On-Site Pilot Plant Systems Alternative

An on-site incineration pilot plant could be constructed to simulate the system and regimes contemplated for incineration of Basin F wastes. Such a pilot plant would have the parameters presented in Table 2.1-1.

The consequent scale-up factor for such a kiln, with a capacity of 2,000-3,000 lb/hr, would be approximately 13 to 20, based on a conceptual system design capacity of 40 tons/hr (20 tons/train). Such a pilot plant would replicate the parameters of the final full-scale design and contribute to the information available for that design.

3.3.2 Mobile Pilot Plant System Alternatives

Several mobile incineration systems are commercially available including both rotary kiln and circulating bed incinerators. Since a rotary kiln system is the selected technology for Basin F wastes (Ebasco 1988a), only those mobile systems using rotary kilns are considered for pilot plant study. Mobile rotary kiln incinerators available for use include (among many) the Environmental Protection Agency (EPA) and the John Zink mobile incinerators.

EPA Mobile Incineration System

The EPA mobile incinerator was designed for complete combustion of polychlorinated biphenyls (PCB) and other hazardous substances.

The mobile incineration equipment is mounted on four trailers. The first trailer contains the solids ram feeder and rotary kiln, which operates around 100°C. The kiln dimensions are 16 ft in length and 4.31 ft inside diameter, for an L/D ratio of 3.7, which is the range required for Basin F wastes. The kiln is lined with a 6-inch castable refractory. It has a design capacity of up to 3 tons/hr. The combustion gases go to the afterburner on the second trailer operating at 1,200°C and then are cooled to 90°C by water sprays in a quench elbow. The gases proceed to the air pollution control equipment on the third trailer where particulate is removed by a high efficiency air filter, and acid gases are neutralized in an alkaline scrubber. An induced draft fan draws the combustion gas through the system to the discharge stack. The fourth trailer contains monitoring and control equipment to measure temperatures, flow rates, and compositions. An in-line stack gas analyzer is also located between the scrubber and fan. The computerized control system includes duplicate automatic shutdown devices; manual controls also are provided.

The EPA mobile incinerator has been rigorously tested since 1981 on PCB liquids, chlorinated organic fluids, and dioxins. During the spring of 1985, the mobile incinerator was field tested at the Denney Farm site in Missouri with dioxin-contaminated solids and liquids. DREs of over 99.9999 percent were achieved, and all ash and scrubber by-products were "delisted" in accordance with EPA guidelines. These trial burns provided valuable technical and economic data as well as demonstrating the viability of on-site incineration.

John Zink Mobile or Fixed Incinerator System

The John Zink Company can supply a mobile incineration system for on-site pilot testing of Basin F wastes. This system would be custom designed and

built specifically for a pilot-scale unit to be installed at the RMA site. The John Zink mobile unit can be furnished in three general kiln sizes:

- o 11.5-ft outside diameter;
- o 8.0-ft outside diameter; and
- o 6.0-ft outside diameter.

A standard 6.0-ft kiln, approximately 20 ft in length, can be used to obtain a L/D ratio of 3.3. This mobile system includes a feed system, afterburner, quench section, venturi scrubber, packed tower scrubber, ash collector, ID fan, stack, and monitoring and control equipment. John Zink also can supply complete civil design, on-site operation, and dismantling service. The kiln is designed to operate at a 1,000°C gas temperature. The afterburner typically operates at 1,200°C with a 2-second gas residence time.

3.3.3 On-Site Installation Considerations

In comparing off-site versus on-site pilot testing, consideration must be given to the fact that on-site installation of a mobile incineration system requires planning and regulatory compliance, legal arrangements, public relations, site preparation and logistics, field shakedown, and, finally, dismantling activities. The following is a brief discussion of these activities for any mobile system.

Planning

Detailed contractors' work plans with the associated health and safety and quality assurance/quality control (QA/QC) documents are necessary for on-site construction.

Regulatory Compliance

As previously indicated, on October 17, 1986, the "Superfund Amendments and Reauthorization Act of 1986" to CERCLA was signed into Law. Section 121 specifies a number of criteria to be considered in determining the

appropriate cleanup standards to be applied to remedial actions taken pursuant to the Act. Subsection 121(b) makes clear that Section 121 applies to the RMA site. Under Section 121(c) no federal or state permits are required for the portion of the removal or remedial action conducted entirely on-site, when carried out according to ARARs.

Legal Arrangements

Legal arrangements may include additional contractual agreements between the involved parties. Such agreements are necessary to define additional liability considerations.

Public Involvement

Public involvement is required in order to obtain public acceptance of on-site incineration, even for the relatively short time frame involved with pilot plant testing. For instance, the EPA considered public relations critical to the success of their Missouri test burn.

Site Preparation and Logistics

A detailed site-specific civil design is required for an on-site pilot plant. A site survey is necessary to establish geographical requirements (incinerator location, access roads, etc.), in addition to the design associated with the incinerator itself (foundations or skids, additional steel structures, prefabricated building, etc.). Related equipment such as storage tanks, additional feed handling equipment, associated office and monitoring trailers, and a decontamination facility are necessary.

Finally, the mobile or permanent incineration pilot plant system must be transported to the site and installed according to the construction plan. Additional construction-related equipment, personnel, and trailers would be mobilized on-site.

Field Shakedown

Field shakedown activities are necessary to check the performance of the system. Such activities may include a start-up on fuel only, and several tests with a prepared control sample to check the monitoring equipment and the required DRE.

3.3.4 Design Requirements

Both the permanent and mobile incineration pilot plant systems have the ability to meet the equipment design specifications required by the conceptual design as described in Table 2.1-1 of this report.

In addition, the operating parameters (temperature, residence times, and excess air) of both the EPA and John Zink systems can be adjusted to test various regimes. In addition to a permanent on-site system, both mobile units contain the components of a full-scale system--solids feed, kiln, afterburner, quench, AQCS, fan, stack, water treatment, ash handling, and monitoring and control equipment. Materials of construction, including refractory, are suitable for full-scale equipment. The pilot plant can be designed and operated in such a way that reliable data for development of the full-scale capital and operating costs can be developed. Both the John Zink and EPA incinerators meet the design criteria described in Table 2.1-1.

As previously indicated, systems could be supplied by other vendors of rotary kilns. Further, this study does not preclude the piloting of other technologies, which could include infrared furnaces, fluidized beds, pyrolyzers, and indirect-fired kilns.

3.4 THE OFF-SITE PILOT PLANT ALTERNATIVE

An off-site incineration pilot plant facility can be a small research-oriented unit, a true pilot-scale incinerator, or a full-scale permitted commercial incinerator. For off-site testing, the hazardous waste would be transported to the off-site facility to be test burned, and the incinerator

residues would then be transported to a licensed disposal facility or back to Rocky Mountain Arsenal. The off-site facility, especially a commercial one, may not offer as flexible a pilot program as the permanent on-site or mobile incinerator alternatives. However, site preparation, construction, field shakedown, and dismantling activities are not required for an off-site pilot test. Permit modifications may be eliminated entirely if the facility's existing permit is sufficient in regard to the type of wastes that can be incinerated. These considerations are discussed in the following subsections. As previously discussed, only those facilities that offer rotary kiln incinerators are considered. Rotary kiln incinerators available include those at Energy and Environmental Research Corporation (EER); John Zink Company; EPA Combustion Research Facility; Chicago Incinerator Facility; Rollins Environmental Services in Deer Park, Texas; and the Allis Chalmer's Process Research and Test Center in Oak Creek, Wisconsin.

3.4.1 Energy and Environmental Research Corporation

The Energy and Environmental Research Corporation rotary kiln is a bench-scale simulator capable of handling 50-75 pounds of waste (approximately 0.5 to 0.75 ft^3) in a batch mode. The unit was designed specifically to identify the combustion regime (time/temperature/turbulence) associated with detoxifying waste in a rotary kiln environment, as well as identifying any problems associated with incinerating solid wastes, such as slagging, delisting residuals, and products of incomplete combustion. This incineration system consists of a kiln with typically a 450,000 Btu/hr capacity and an afterburner with 150,000 Btu/hr capacity. The auxiliary fuels used in the kiln and the afterburner are natural gas, fuel oil, or liquid wastes. An ID fan ensures operation under negative pressure. Solid and gas phase sampling is performed to follow the thermal decomposition profile of the solid waste feed. This system is not compatible with the conceptual design requirements.

3.4.2 John Zink Company Pilot Plant

The John Zink pilot plant incineration facility includes an oil-fired refractory-lined kiln 5 ft in diameter and 15 ft in length (an L/D ratio of 3.0). The unit has a total heat input capacity of 3 million Btu/hr and can handle up to 2,000 lb/hr at a 30-minute solids residence time. The unit also includes an afterburner, quench section, venturi scrubber, and ID fan. The kiln can be run with temperatures up to 1,300°C. Light distillate fuel oil can be used as an auxiliary fuel. Full analytical capabilities for solid and gas samples are available. The John Zink pilot facility is RCRA Part B permitted.

3.4.3 EPA Combustion Research Facility

The EPA Combustion Research Facility (CRF) incineration pilot plant is operated by Acurex Co. It now performs tests only for the EPA, although there is some discussion that the pilot plant will be made available for other clients. The current Acurex-EPA contract would have to be changed for this availability to exist.

The CRF facility is a rotary kiln with afterburner. Supporting the kiln is a small solids feed system, an air quality control system, an extensive monitoring operation, and associated controls. The kiln dimensions are 8 ft long and 4 ft inside diameter, with an L/D ratio of 2. The kiln has a maximum temperature of 900°C. The kiln is limited to the nonslagging region due to the type of refractory installed. The lining is a low-density, high alumina castable refractory. It does not perform well at high temperatures. Further, when the unit is operated in excess of 760°C, the kiln skin temperature reaches 170-200°C, indicating poor refractory and insulation. The kiln is fired with propane gas and operates in the region of 10 percent O_2 (90 percent excess air) in the dry stack gas compared to a desirable level of 7 percent O_2 (50 percent excess air).

The afterburner of the system is oriented horizontally. Its dimensions are 10 ft in length and 3 ft in diameter. Its lining is 6-in. thick alumina castable refractory. Its maximum temperature is 1,200°C. The capacity of the unit, in heat input, is 2 million Btu/hr in the kiln and 3 million Btu/hr total. The secondary burner has a capacity of 1.8 million Btu/hr. The afterburner also is fired with propane and has an O_2 level of 5 to 6 percent (30 to 40 percent excess air) as a desired level, although 10 percent O_2 (90 percent excess air) is also used. The capacity of the CRF as measured by solids feed is ash-pit limited, and in the case of burning Basin F wastes, would be about 250 lb/hr. This presents a scale-up factor of approximately 100, which is at the extreme limit of acceptability.

The unit rotates about 5 rpm and has a solids retention time of 30 to 60 minutes (depending upon speed). The afterburner has a typical gas residence time of 2 seconds. The air pollution control system includes a venturi scrubber and a packed tower.

The CRF has the capability to determine whether a rotary kiln is appropriate for incinerating wastes. However, upon inspection, it is apparent that the unit does not have sufficient flexibility to be used for optimizing the combustion regime, or for obtaining operating (including economic) information. Further, the kiln design parameters (L/D ratio and operating temperature) are insufficient to replicate the conceptual design kiln conditions. Also, the afterburner is horizontal, not vertical.

3.4.4 Allis-Chalmers Pyrokiln System

Allis-Chalmers has an incineration facility at Oak Creek, Wisconsin. This facility is currently treating alpha and beta naphthylamines at concentrations of 75 to 250 ppm. The system includes the following unit operations: feed preparation and sizing, rotary dryer, rotary kiln, rotary cooler, spray tower, and baghouse. The rotary kiln is a cocurrent unit with three zones: dryer and preheat (some volatiles liberated), ignition zone

(combustion begins), and afterburner zone (provides additional residence time at higher temperatures). Solids and gas residence times are presented below:

Zone	Solids Residence, min.	Gas Residence, sec.
Drying/Preheating	5-10	0.33
Volatilization/Combustion	10-20	0.67
Afterburning	15-30	1.00
Totals	30-60	2.00

The thermally treated residue exits the kiln and is cooled and moisturized in a rotary cooler. Particulate is collected to 99.7 percent. The rotary kiln is 7.5 ft in diameter by 45 ft long (L/D ratio of 6), operates at 900-1,000°C, has excess air levels of 20 percent, is fired on natural gas, and has a capacity of 10 tons/hour (40 x 10^6 Btu/hr maximum). Feed material is sized at 2 inches minus.

3.4.5 Commercial Incineration Facilities

Commercial incineration facilities that have the ability to replicate the full-scale system design parameters and the ability to minimize scale-up to the full-scale system could be used. Such facilities include the Rollins Environmental Services facility in Deer Park, Texas, and the Chemical Waste Management/SCA facility in Chicago, Illinois.

The Rollins commercial incinerator facility, which is RCRA permitted, is capable of handling bulk and containerized liquids and solids including pesticides, PCBs, and contaminated soils. Rollins uses a variety of processes, including rotary kiln incineration, and offers truck or rail access, laboratory analyses, and transportation services.

The SCA Chicago facility is a commercial, RCRA permitted incineration facility that can accept bulk and containerized liquids and solids including pesticides and PCBs. The facility utilizes a rotary kiln incinerator for solid wastes and can accept tank truck or rail car delivery for immediate incineration or temporary on-site storage. Full analytical capabilities are available at the SCA facility. SCA also offers waste transportation services.

3.4.6 Conclusion

Of the off-site facilities identified in this investigation only the John Zink pilot plant and commercial incineration facilities are capable of replicating the full-scale design parameters as indicated in Table 3.4-1. Commercial incineration facilities, however, offer significantly less flexibility because of the following reasons:

- Cannot test failure modes;
- Scheduling concerns related to the long-term availability of the unit;
- Must operate within their airborne emission permit conditions;
- Can only incinerate materials that they have a license for; and
- Are not instrumented or designed to operate as a specially designed research facility.

The biggest concerns relate to the inability to test failure modes and scheduling. A commercial or industrial facility cannot test failure modes as this would be outside of their permit conditions. Scheduling or system availability is an important part of a research pilot plant. It is not possible to accurately schedule the amount of time required to solve a problem with a commercial or industrial kiln because of the unknown aspects of the tests to be conducted. As such, scheduling could significantly affect the program.

TABLE 3.4-1

FACILITIES ABLE TO ACHIEVE FULL-SCALE DESIGN PARAMETERS

Facility	Acceptable	Reasons
EER Corporation	No	Batch Mode Operation and Size Limited
EPA Facility	No	Feed Rate Limited, Low L/D Ratio, and Temperature Limited
John Zink	Yes	RCRA Part B Permitted and Meets Design Parameters
Allis-Chalmers	Maybe	Operating Facility with a High L/D Ratio
Commercial Incineration Facilities	Yes	RCRA Permitted and Meets Design Parameters. Cannot Test Failure Modes and Cannot Operate as Research Tools

Vendor-offered facilities (such as the John Zink pilot plant) are the preferred option for off-site incineration studies. Very few of these facilities are available. John Zink is a representative facility. Before selection of a vendor, a bid document would be prepared so that interest from other parties could be solicited.

4.0 SELECTION OF THE PILOT PLANT ALTERNATIVE

4.1 EVALUATION

Four alternatives were evaluated for the pilot plant:

- o The No Pilot Plant Alternative;
- o The Building 1611 Pilot Plant Alternative;
- o The On-Site Permanent or Mobile Pilot Plant Alternative; and
- o The Off-Site Pilot Plant Alternative.

As previously discussed in Section 3.0, the No Pilot Plant Alternative and the Building 1611 Pilot Plant Alternative cannot replicate the full-scale incinerator design parameters. As a result, these alternatives are no longer considered. This leaves only the On-Site Permanent or Mobile Pilot Plant Alternative and the Off-Site Pilot Plant Alternative.

The Off-Site Pilot Plant Alternative includes a commercial incineration facility or a pilot plant facility operated by a vendor. As indicated in Section 3.4, none of the available commercial facilities are suitable as a pilot unit mainly because of their inability to test failure modes and operate as a research tool. The pilot plant(s) operated by vendor(s) are primarily used to test the performance of the equipment manufactured by the individual vendors. Moreover, to use an off-site facility, substantial volumes of Basin F wastes would have to be transported. The cost and risk (possibility of spills) associated with the transportation of Basin F wastes are substantial.

Furthermore, off-site incinerators are capable of providing only limited data for full-scale system optimization, since the configuration and operating parameters are already established. Therefore, the On-Site Permanent or Mobile Pilot Plant Alternative offers the most flexibility.

There are two options available under the On-Site Permanent or Mobile Pilot Plant Alternative. If a long-term (6-9 month) pilot program is needed, the cost associated with leasing a mobile unit could be higher than constructing a permanent unit at RMA. For example, the cost of leasing the EPA incineration unit, including costs related to site preparation, operations, and transportation, would be $15,000/day. This figure is based on the costs associated with the Missouri trial burn. The pilot program for Basin F would be comparable to the Missouri trial burn. Therefore, the monthly minimum capital expenditure for leasing a mobile pilot plant could be $450,000.

Alternatively, a small rotary kiln/afterburner installation costs approximately $400,000, including equipment, installation, and engineering. Total system costs, including the air pollution control equipment, material handling, and ancillary systems, would probably increase the installed cost to $1,200,000 to $1,600,000. If a 6-9 month duration is expected for the pilot plant program, it would be less expensive to construct an on-site facility. An on-site permanent facility has the following advantages:

- Facility would be available for use at all times;
- Could operate as a research tool;
- Could be designed to replicate full-scale design parameters;
- There would be no off-site shipping liability; and
- The acceptance of incineration by the public would be tested.

4.2 RECOMMENDATIONS

It is recommended that an on-site permanent incinerator pilot plant be constructed at RMA. The mobile EPA incinerator, which could be used, is fairly expensive for a 6-9 month program, and its availability for that period of time is doubtful. Further, vendors have indicated that they would recover the costs of a mobile unit in the leasing agreement.

As part of the recommendation for the on-site program, it may be desirable to evaluate the use of a down-fired liquid incinerator to thermally treat the Basin F liquid separate from the contaminated soil. This could be done using the AQCS train from the on-site unit and either installing a separate liquid incinerator or designing the afterburner to operate as a down-fired liquid incinerator. In this way, the Basin F liquids could be evaluated in three ways: cofiring in the kiln, injection into the afterburner along with the off-gases from the kiln, or operation of the afterburner or separate liquid incinerator.

Appendix A

RESPONSE TO SHELL OIL COMMENTS

APPENDIX A
RESPONSES TO SHELL OIL COMMENTS

A copy of the original letter of the Shell Oil comments is on file at PMO.

Only comments applicable to the report titled "ANALYSIS OF PILOT PLANT ALTERNATIVES FOR THE INCINERATION OF BASIN F WASTES AT ROCKY MOUNTAIN ARSENAL," dated March 1987 are presented here. Comments have been incorporated into the final white cover version of the subject report dated September 1988.

COMMENT NO. 1

This is a fairly comprehensive, logical report, given the constraints of (1) rotary kiln incineration and (2) operating conditions determined by the laboratory tests. In general the report describes the various requirements/goals of a pilot plant program realistically but there are also several options that are not considered:

No consideration is given to separating the two primary wastes types from Basin F, i.e., Basin F liquid and Basin F solids. Given the alkali present in the liquid wastes, kiln performance could be seriously jeopardized. This point is reinforced by the fact that most, if not all, commercial incineration facilities expressed reluctance to burn the Basin F liquid in their rotary kiln facilities. Co-mingling of the two waste forms would seriously complicate rotary kiln incineration of the solids. The ash produced from burning of a mixed waste which contains a high level of soluble salts would also be more difficult to stabilize or fix than a solid waste not containing soluble salts.

Throughout the report there is no attempt to address the fact that the kiln would be expected to handle a salt rich liquid waste as well as solids. The feed is referred to quite simply as Basin F waste.

RESPONSE TO COMMENT NO. 1

The final white cover version of the Full-Scale Conceptual Design report and the conclusions of the subject report have been changed to reflect the use of a down-fired liquid incinerator, thus separating the liquid from the solid waste. However, cofiring of the waste is evaluated.

COMMENT NO. 2

The claim that a down-flow afterburner would prevent alkali attack of refractory is not true. A down-flow unit would possibly reduce attack and facilitate draw-off of salt but significant refractory damage should still be expected with the salt levels of Basin F liquid.

RESPONSE TO COMMENT NO. 2

The implication that the down-fired afterburner would prevent refractory attack was not intended and has been corrected in the final white cover version of the subject report. It is realized that refractory attack by alkali is an important concern for future evaluation before the design of a full-scale facility. However, the down-fired afterburner configuration proposed for the pilot plant and the conceptual design is similar to that employed on T-Termal's LIQUI-DATUR(R) SYSTEM and on other systems (except for the operating temperature) such as those manufactured by John Zink.

COMMENT NO. 3

It is noted that, to date, most of the mobile rotary kiln experience has been with PCB's or dioxin containing wastes and except for the recent Times Beach pilot operation, none have considered the treatment of contaminated soils. What is not mentioned is that large-scale experience based on the pilot test studies at Times Beach is

non-existent and therefore the correlation of pilot scale tests with commercial-scale are also not proven.

RESPONSE TO COMMENT NO. 3

The authors believe that the rotary kiln technology for mobile and fixed systems is well developed and a proven technology for thermal treatment of contaminated soils. This can be readily seen by the inclusion of incineration in EPA Record Of Decisions and other feasibility study work around the country. It can also be seen in the large investment that companies like Ensco, IT Corporation, Roy Weston, Rollins, Chemical Waste Management, John Zink, Von Roll, Vesta, M&C, and many others are putting into the use of rotary kiln technology. Further successful test burns have taken place at the Cornhusker Army Ammunition Plant; the U.S. Air Force at Gulf Port, Mississippi; Times Beach; and other sites. The thermal treatment of soil by incineration is also planned for the following sites: Lenz Oil site (15,000 tons), Arco Alaska (45,000 tons), Verta site in Louisiana (120,000 tons), Bog Creek Farm, Coleman Evans, and other locations. However, it is realized that pilot plant work is an important requirement for the application of incineration to any given site remediation.

COMMENT NO. 4

In surveying available facilities no mention is made of the rotary kiln-based facilities of Allis-Chalmers in Wisconsin.

RESPONSE TO COMMENT NO. 4

A brief discussion of the Allis-Chalmers facility has been added to the subject report.

COMMENT NO. 5

The John Zink facility is considered the preferred choice based on the general test facilities and the ability of the Zink kiln to meet full-scale design parameters. What is not discussed is the general absence of a significant experience base by John Zink in the rotary kiln incineration of contaminated soils except with recent pilot plant studies.

RESPONSE TO COMMENT NO. 5

Page 3-25 of the subject report states "Vendor-offered facilities (such as the John Zink pilot plant) is the preferred option for off-site incineration studies." It is not the purpose of this study to evaluate all such facilities or to select a single vendor. Further, the authors have no preference for the John Zink Company since many other vendors can supply the same services.

COMMENT NO. 6

It cannot be over-emphasized that conducting pilot plant studies in cooperation with experienced designers and vendors of incineration processes should be the preferred choice. The fact that this experience is primarily based in Europe should not be discounted on the basis of currently undefined concerns for waste transport off-site for pilot scale studies.

RESPONSE TO COMMENT NO. 7

It is agreed that there is considerable experience in Europe. It is not the purpose of the subject report to select a vendor for pilot testing.

COMMENT NO. 7

Table 2.0-1 - Note that the bench-scale study set variables are based on literature and tested only for incinerability. The "full scale concept design" sets out (in first paragraph of Executive Summary) the limitations presented by limited data and "conventional" orientation. The above notwithstanding, this study more or less adopts the level of variables from the above two studies. We thus "lock in" on a very conceptual design with optimization only within conventional operating parameters.

RESPONSE TO COMMENT NO. 7

The values in the subject table are specific to rotary kiln/afterburner systems. The table values (now Table 2.1-1) have been changed in the final white cover version of the subject report to incorporate the piloting of low temperature volatilization in the rotary kiln or other such reactor. Further, the table values are only a guide, they are not cast in concrete at this level of study.

COMMENT NO. 8

Page 2-2, section 2.1.3. Included in this discussion should be testing of the fates of metals (As, Hg, etc.) and demonstration of emission controls to meet local conditions. Also operability (as opposed to maintenance) as affected by alkali salts, i.e., deposition on critical surfaces, should be evaluated.

RESPONSE TO COMMENT NO. 8

The above comment points are important for any pilot plant work. However, this information is not required to select a pilot plant alternative.

COMMENT NO. 9

Page 2-4, paragraph 2.2.1. The rational for picking 6 percent kiln loading over some other value is not clear. Typical loadings of 5 to 15 percent make this a conservative value. In pilot plant operations loading should cover the typical range for a complete evaluation.

RESPONSE TO COMMENT NO. 9

Low kiln loading reduces the mass emission rate of particulates and also improves the heat transfer rate to the solids.

COMMENT NO. 10

Page 3-6, section 3.1.3. Another reason for rejecting the NO-Pilot alternative is the penalty for failure resulting from the public's sensitivity to incinerators, i.e., you may not be allowed to "tune" the commercial unit. If it does not work from day one, it will not be operated.

RESPONSE TO COMMENT NO. 10

The above comment point is well taken and agreed with.

COMMENT NO. 11

Page 3-10, paragraph 3.2.3. Why is countercurrent gas flow a problem? Countercurrent flow will result in lower flame temperatures to achieve the desired solids temperature.

RESPONSE TO COMMENT NO. 11

A discussion on cocurrent versus countercurrent burner location has been added to the subject report.

COMMENT NO. 12

Page 3-12, second sentence. This statement is not correct: the selection of technologies for Basin F wastes is subject to FS procedures.

RESPONSE TO COMMENT NO. 12

The rotary kiln technology was selected as the basis for the Task 17 investigation only.

COMMENT NO. 13

Table 3.2-1. The selection of a L/D ratio of 3.3 is not explained. A short kiln will require higher flame temperatures to guarantee the desired solids temperature.

RESPONSE TO COMMENT NO. 13

A low L/D ratio was selected to reduce particulate emissions from the kiln. A L/D ratio of between 3 and 4 is typical of the available mobile rotary kiln incinerators as well as fixed units.

COMMENT NO. 14

Page 3-15. It may be good strategy to proceed with on-site piloting just to test public reaction to incineration on the RMA. If it is not accepted, use of a full scale system may be precluded. This reaction may not be determined if piloting is off-site.

RESPONSE TO COMMENT NO. 14

This point has been incorporated into the final white cover version of the subject report.

COMMENT NO. 15

Page 4-2, section 4.1. A 6 to 9 month pilot program seems excessive. The life expectancy of the full-scale operation is anticipated to be only 2.5 years. Surely the operating requirements can be determined in a shorter time frame. A two step pilot program is suggested. The first step would be composed of several runs made in vendors' test facilities equipment. These systems would be smaller than the on-site system. Operating parameters such as kiln loading, L/D ratio, retention time, and cocurrent vs countercurrent gas flow could be better defined in existing equipment.

RESPONSE TO COMMENT NO. 15

The operating life of the pilot plant will be determined by the types of materials at RMA that may require incineration. The operating period could very well be reduced to 3 to 6 months. The idea of the two-stage on-site program is well taken. Countercurrent operation has been ruled out as discussed in Section 2.2.5 of the subject report.

Appendix B

RESPONSE TO EPA REGION VIII COMMENTS

APPENDIX B

RESPONSE TO

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION VIII COMMENT

A copy of the original letter of the EPA Region VIII comments is on file at PMO.

Only comments applicable to the report titled "ANALYSIS OF PILOT PLANT ALTERNATIVES FOR THE INCINERATION OF BASIN F WASTES AT ROCKY MOUNTAIN ARSENAL" dated March 1987 are discussed here. In the EPA letter this comment is presented under the heading C. PILOT TESTS.

COMMENT NO. 1

Sub-scale testing of incineration processes is of limited utility unless substantially full-scale equipment is used. This reflects the fact that the "success" of incineration equipment (in achieving satisfactory remediation) involves the interplay of a complex array of processes. Usually, the controlling scaling parameters in the system are unknown. Those that are not are often non-linear and difficult to measure... such as radiative heat transfer to the incoming soil or the mixing processes in the kiln and in the flows downstream. Further, experience has shown that refractory effects, volatilization of heavy metals and other important aspects of the process are not well-replicated between pilot and prototype.

Therefore, we do not believe that the pilot program produced meaningful data for or against the applicability of the rotary kiln.

RESPONSE TO COMMENT NO. 1

The purpose of the subject report is to evaluate the following alternatives: not having a pilot plant and going directly to a full-scale system, using the incinerator in Building 1611 for a pilot

plant, using an on-site or mobile pilot plant, or using an off-site pilot plant. Any pilot plant alternative selected involves the use of a system with a design capacity within an order of magnitude of the full-scale system. The design capacity of the full-scale system is 40 tons/hour as described in the report titled "Full-Scale Incineration System Concept Design for Basin F Wastes at Rocky Mountain Arsenal," dated September 1988. This capacity is within the order of magnitude range of many existing full-scale incineration systems.

Appendix C

REFERENCES

APPENDIX C
REFERENCES

Ebasco (Ebasco Services Incorporated). 1987. Final Laboratory Test Plan for Incineration of Basin F Wastes at Rocky Mountain Arsenal. April. Prepared for U.S. Army Program Manager's Office for Rocky Mountain Arsenal Contamination Cleanup.

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